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Attached is a full English translation of JP 02-145217 A.

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If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Roy V King can be reached on 571-272-1244. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

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ELECTRIC DISCHARGE DEVICE FOR TURBINE ROTOR
[Taabinroota no houdenkakousouchi]

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SPECIFICATION /123*

1. Title of the Invention

Electric Discharge Device for Turbine Rotor

2. Claim

An electric discharge device for turbine rotors characterized by comprising: a machining fluid tank provided on a bed; a tilting rotary table which is provided inside said machining fluid tank and which rotates a turbine rotor for indexing by holding said turbine rotor; a first machining head and a second machining head which are provided on beds with said tilting rotary table sandwiched between them and which are supported in a manner such that they can be freely positioned against the tilting rotary table; electrode hands which are provided to the end parts of said first machining head and said second machining head on the sides of the tilting rotary table and which hold machining electrodes that are for machining the blades of the turbine rotor; electrode replacing devices which are provided to the first machining head and the second machining head and which are equipped with racks for storing pluralities of the machining electrodes and which are equipped with replacing means for replacing the machining electrodes between said racks and the electrode hands; and an NC device for rotating the tilting rotary table, for moving and positioning the first machining head and the second machining head, and for controlling the replacing of the machining electrodes carried out by the electrode replacing devices.

* Numbers in the margin indicate pagination in the foreign text.

3. Detailed Explanation of the Invention

<Field of Industrial Application>

The present invention pertains to electric discharge devices utilized for machining turbine rotors.

<Related Art>

A turbine is a machine that generates mechanical rotary power from fluid flows. Rotary power is generated via a turbine rotor in which many blades (rotary blades) are provided on the outer periphery of a disk.

Figure 3 is a perspective drawing of a turbine rotor utilized for a small engine, etc. The turbine rotor [1] comprises a shaft-like rotor [4] and a disk [2] provided on one end of the rotor [4]. The outer periphery of the disk [2] has many blades [3] integrally dispose on it. /124

Figure 4 shows the finished condition of the blade [3] that has been subjected to conventional electric discharging. If the number of blades [3] of the turbine rotor [1] is small, rough machining is carried out by means of precision casting in order to form a profile (blade profile). After the blades [3] are formed on the outer periphery of the disk [2] by means of the precision casting, the profiling of the blades [3] becomes finished by means of electric discharging. In the finish machining of the blades [3] carried out by means of electric discharging, the profile is formed by allowing a round electrode [5] to move two-dimensionally (orbital motion) on the outer peripheries of the blades [3] in the direction [W] while being rotated it in the direction [V].

When the number of blades [3] of the turbine rotor [1] is large, precision casting of the blades [3] is technically impossible. When

precision casting is impossible, machining is normally carried out. However, milling is also impossible since the material forming the blades [3] and the disk [2] is a material difficult to machine, and therefore, the profile formation has to depend on electric discharging. Figure 5 shows a rough-finishing condition in which the blades [3] are subjected to electric discharging. Figure 6 shows a finish-machining condition of the blades [3]. The direction indicated by the arrow [a] in Figure 5 runs from the circumference of the disk toward the inside of the circumference.

Rough finishing of the blades [3] carried out by means of electric discharging is carried out with a rough-finishing form electrode [22]. By moving the rough-finishing electrode [22] in the direction [a] from the outer periphery of the disk [2], a margin [7] for rough-machining becomes removed and a rough profile is formed. After the rough machining, the blades [3] are subjected to intermediate finishing and final finishing. In the same manner as the above-described finish machining carried out when the number of the blades [3] is small, the intermediate finishing and final finishing are carried out by allowing the round electrode [5] to move two-dimensionally (orbital motion) in the direction [W] on the outer peripheries of the blades [3] while being rotated in the direction [V]. Thus, a margin [38] for finishing is removed and the profile formation is completed.

<Problems that the Invention is to Solve>

However, when the finish machining for profile formation is carried out by means of a round electrode, the profiles become unsteady and the thicknesses of the blades become uneven when the round electrode becomes

consumed and thin during the electric discharging. If the thicknesses of the blades become uneven, retention of balancing accuracy and a high efficiency becomes adversely affected during the revolution of the turbine rotor. It is necessary to frequently replace the round electrode in order to eliminate the unevenness of the blades, but frequent replacement of the round electrode extends the machining cycle time due to a reduction in the operation efficiency. This is a major obstacle in the early development of high-efficiency turbines.

The invention was completed in order to solve the above shortcoming, and its purpose is to supply an electric discharge device for turbine rotors capable of performing the rough machining and finish machining for the profile formation of a turbine rotor in a short period of time. The purpose is also to obtain high-quality turbine rotors and to shorten the machining cycle time.

<Means for Solving the Problems>

The invention is characterized by comprising: a machining fluid tank provided on a bed; a tilting rotary table which is provided inside said machining fluid tank and which rotates a turbine rotor for indexing by holding said turbine rotor; a first machining head and a second machining head which are provided on beds with said tilting rotary table sandwiched between them and which are supported in a manner such that they can be freely positioned against the tilting rotary table; electrode hands which are provided to the end parts of said first machining head and said second machining head on the sides of the tilting rotary table and which hold machining electrodes that are for machining the blades of the turbine

rotor; electrode replacing devices which are provided to the first machining head and the second machining head and which are equipped with racks for storing pluralities of the machining electrodes and which are equipped with replacing means for replacing the machining electrodes between said racks and the electrode hands; and an NC device for rotating the tilting rotary table, for moving and positioning the first machining head and the second machining head, and for controlling the replacing of the machining electrodes carried out by the electrode replacing devices.

<Operation of the Invention>

The first machining head moves to the turbine rotor attached to the tilting rotary table and machines it by means of the machining /125
electrode held by the electrode hand. After the machining by the first machining head is finished, the tilting rotary table rotates for indexing until the next part of the turbine rotor to be machined reaches the location of the first machining head, and the first machining head performs the next machining. When the part that was machined first by the first machining head reached the location of the second machining head by means of rotation, the first machining head and the second machining head perform machining simultaneously. The simultaneous machining is carried out until the part that was machined first by the second machining head returns to the first machining head. When the part that was machined first by the second machining head returns to the first machining head, the machining by the first machining head ends and the first machining head stops. As for the single machining by the second machining head and the indexing rotation of the tilting rotary table, the single machining by the second machining

head ends after the part immediately before the part that was machined first by the second machining head and that reached the second machining head after going through the first machining head is finished. Exhaustion of the machining electrodes in the middle of electric discharging is detected before it occurs and the electrodes are replaced by means of the electrode replacing devices at appropriate replacement timings. The movement of the first machining head and the second machining head, the indexing rotation of the tilting rotary table, and the replacing of the machining electrodes are controlled by the NC device.

<Embodiment of the Invention>

In the following, one working example of the invention will be explained concretely based on drawings. Figure 1 is a perspective drawing of the electric discharging device of one embodiment of the invention, and Figure 2 is a partial magnified drawing of the electric discharge device of one embodiment of the invention. The object of machining is the turbine rotor shown in Figure 3. The same reference numerals have been assigned to members identical to those in Figure 3, and overlapped explanations will be omitted.

A machining table [10] is disposed on a bed [9]. A machining fluid tank [11] is disposed at the center of the machining table [10], and the machining fluid tank [11] has an open top and a door [15] at the front that can be opened and closed. A machining fluid is supplied to the machining fluid tank [11] by means of the machining fluid supply device (omitted in the drawing), and the supplied machining fluid becomes discharged from the machining fluid tank [11]. A tilting rotary table

[12] having a turbine rotor, which is the object of machining, attached to it is disposed at the center area inside the machining fluid tank [11], and the tilting rotary table [12] can rotate the turbine rotor [1] for the indexing of the blades [3]. On either side of the machining table [10], there are a first supporting base [13] and a second supporting base [14] with the machining fluid tank [11] sandwiched between them. The upper part of the first supporting base [13] and the upper part of the second supporting base [14] have the main unit [18] of a first machining head and the main unit [19] of a second machining head attached to them. A first head [36] and a second head [37] are provided to the end parts of the main unit [18] of the first machining head and the main unit of the second machining head on the side of the machining fluid tank [11]. Moreover, the front ends of the first head [36] and the second head [37] are provided with a first electrode hand [20] and a second electrode hand [21]. The fist electrode hand [20] and the second electrode hand [21] can retain an electrode [22] for rough machining (machining electrode) and an electrode [23] for finish machining (machining electrode) in a detachable manner. The first electrode hand [20] and the second electrode hand [21] retaining the electrode [22] for rough machining and the electrode [23] for finish machining are located inside the machining fluid tank [11].

The main unit [18] of the first machining head and the main unit [19] of the second machining head are provided with a first electrode replacing device [26], which is an electrode replacing device, and a second electrode replacing device [27], which is an electrode replacing device, and the first electrode replacing device [26] and the second electrode

replacing device [27] are provided with a first electrode rack [31] and a second electrode rack [32]. The first electrode rack [31] and the second electrode rack [32] are equipped with many electrodes [22] for rough machining and electrodes [23] for finish machining on their outer peripheries in a detachable manner. The first electrode replacing device [26] and the second electrode replacing device [27] are provided with electrode replacing arms, which are means for exchanging electrodes [22] for rough machining and electrodes [23] for finish machining between the first electrode hand [20] and the first electrode rack [31] and between the second electrode hand [21] and the second electrode rack [32]. In this manner, the first machining head [16] comprises the main unit [18] of the first machining head, the first head [36], the first /126
electrode hand [20], and the first electrode replacing device [26], and the second machining head [17] comprises the main unit [19] of the second machining head, the second head [37], the second electrode hand [21], and the second electrode replacing device [27].

It will be assumed that the directions in which the first machining head [16] and the second machining head [17] move close to or away from the tilting rotary table [12] are on Z-axis, that the perpendicular directions that cross Z-axis at right angles are on Y-axis, and that the horizontal directions that cross Z-axis at right angles are on X-axis. The main unit [18] of the first machining head and the main unit [19] of the second machining head are attached to the first supporting base [13] and the second supporting base [14] in a manner such that they can move in the directions of X-axis, Y-axis, and Z-axis and can thus be moved

and positioned against the tilting rotary table [12].

The first head [36] and the second head [37] are attached in a manner such that they can rotate around a first supporting shaft [24] and a second supporting shaft [25], which are extended in parallel to X-axis.

After the tilt angles and the locations on X-axis and Y-axis of the electrode [22] for rough machining and the electrode [23] for finish machining have been adjusted with respect to the turbine rotor [1] attached to the tilting rotary table [12], profile formation of the turbine rotor [1] is performed by means of electric discharging in full automation.

The first machining head is controlled to move in the directions of X, Y, and Z-axes and performs electric discharging while allowing the electrode [22] for rough machining to contact the disk [2] of the turbine rotor [1] attached to the tilting rotary table [12]. By the movement of the main unit [18] of the first machining head [18], the electrode [22] for rough machining becomes controlled in the direction in which it moves from the circumference of the disk [2] toward the inside of the circumference and in the direction in which it moves away from the circumference of the disk [2]. After the rough machining of a blade [3] has been performed, the electrode [22] for rough machining moves away from the disk [2] and stands by at the home position of machining until the next rough machining. The tilting rotary table [12] rotates the turbine rotor [1] by A degrees (360 degrees/number of blades) for indexing. When the tilting rotary table rotates by A degrees for indexing, the electrode [22] for rough machining which had been standing by at the machining home position moves again from the circumference of the disk [2] toward the

inside of the circumference and performs electric discharging on the second blade [3] while allowing the electrode [22] for rough machining to contact the disk [2]. After the rough machining of the second blade [3] is finished, the electrode [22] for rough machining moves away from the disk [2] from the circumference of the disk [2] and stands by at the machining home position again, and the turbine rotor [1] rotates by A degrees for indexing. The rough machining performed by the movement of the electrode [22] for rough machining and the A-degree indexing rotation of the turbine rotor [1] are repeated in the same manner until the first blade [3] reaches the location of the second machining head [17]. It will be hypothesized that the number of the repetitions that take place before the first blade [3] reaches the location of the second machining head [17] is N.

After the A-degree indexing rotation of the turbine rotor [1] has been repeated N times, the first blade [3] reaches the location of the second machining head [17]. At the same time as the first blade [3] reaches the location of the second machining head [17], the Nth blade [3] that has not been machined yet reaches the location of the first machining head [16].

The second machining head [17] is controlled to move in the directions of X, Y, and Z-axes and performs finish machining on the first blade [3] that has already been rough finished. The electrode [23] for finish machining provided to the front end of the second machining head [17] has the same shape as the finished surfaces observed between the blades [3]. The finishing margin is removed by means of electric discharging by moving the electrode [23] for finish machining toward the disk [2],

from which the margin for rough machining has been removed, in the direction from the circumference of the disk [2] toward the inside of the circumference. At the same time as the electrode [23] for finish machining performs the finish machining of the first blade [3], the electrode [22] for rough machining also performs rough machining on the Nth blade [3]. When the finish machining of the first blade [3] and the rough machining of the Nth blade [3] are finished, the electrode [22] for rough machining and the electrode [23] for finish machining move away from the disk [2] and stand by at the machining home positions. When the electrode [22] for rough machining and the electrode [23] for finish machining are standing by, the turbine rotor [1] rotates by A degrees for /127
indexing, the first blade [3] advances to the first machining head [16] side, and rough machining and finish machining are simultaneously performed again by the electrode [22] for rough machining and the electrode [23] for finish machining. The simultaneous machining performed by the electrode [22] for rough machining and the electrode [23] for finish machining is repeated (as many times as the number obtained by subtracting N from the number of blades) until the first blade [3] that has been subjected to finish machining reaches the location of the electrode [22] for rough machining. When the first blade [3] reaches the location of the first machining head [16], the electrode [22] for rough machining retreats to the home position of the device and the rough finishing of the turbine rotor [1] is finished.

After the electrode [22] for rough machining has finished performing rough machining, the turbine rotor [1] rotates by A degrees for indexing

N more times, and finish machining is executed by the movement of the electrode [23] for finish machining. After finish machining has been performed N times by the electrode [23] for finish machining, the electrode [23] for finish machining moves from the circumference of the disk [2] and away from the disk [2] and retreats to the home position of the device. The electrode [23] for finish machining retreats to the home position of the device, and the electric discharging performed by the electric discharge device [8] of the turbine rotor of this embodiment becomes finished.

During electric discharging, exhaustion of the electrode [22] for rough machining and of the electrode [23] for finish machining is detected by means of the NC device before it occurs. When exhaustion of the electrode [22] for rough machining and the electrode [23] for finish machining is detected, the are sequentially replaced with the replacement electrodes equipped in the first electrode rack [31] and the second electrode rack [32].

According to the electric discharge device [8] of this embodiment, the first machining head is provided with an electrode [22] for rough machining and the electrode [23] for finish machining is provided to the second machining head [17]. Therefore, it is possible to perform rough machining and finish machining on the blades [3] simultaneously. The tilting rotary table [12] can rotate by A degrees for indexing and can machine the blades [3] by means of electric discharging in continuous automation by rotating the turbine rotor [1] by A degrees for indexing. Since exhaustion of the electrode [22] for rough machining and the

electrode [23] for finish machining is detected before it occurs and automatic replacing is carried out, electric discharging can be performed by means of unexhausted electrodes at all times. Therefore, it is possible to prevent the thicknesses of the blades [3] from being uneven and to achieve high-precision profile formation.

<Effects of the Invention>

Since a first machining head and a second machining head that are independent from each other are provided to a single electric discharge device and the indexing rotation of the tilting rotary table and the movements of the first machining head and the second machining head are controlled by means of the NC device, two types of machining can be simultaneously performed on a turbine rotor in a single step. Since the exhaustion of the machining electrodes that are in the middle of electric discharging is detected before it occurs by means of the NC device and the electrodes can be replaced by means of the electrode replacing devices at appropriate timings, unexhausted electrodes can be utilized at all times and the turbine rotor can be machined by means of electric discharging in continuous automation.

Since turbine rotors can be machined by means of electric discharging in a single step in continuous automation, the machining cycle time can be shortened. Moreover, unexhausted electrodes can be utilized as the machining electrodes at all times, making it possible to perform high-precision electric discharge machining.

4. Brief Explanation of the Drawings

Figure 1 is a perspective drawing of the electric discharge device of one embodiment of the invention. Figure 2 is a partial magnified drawing of the electric discharge device of one embodiment of the invention. Figure 3 is a perspective drawing of a turbine rotor. Figure 4 is a drawing showing the finished condition of a blade that has been subjected to the conventional electric discharge machining. Figure 5 is a drawing showing the condition of a blade being subjected to rough machining by means of electric discharging. Figure 6 is a drawing showing the condition of a blade being subjected to finish machining.

The reference numerals in the drawings indicate the following.

[1] = turbine rotor

[8] = electric discharge device

[11] = machining fluid tank

[12] = tilting rotary table

[16] = first machining head

[17] = second machining head

[20] = first electrode hand

[21] = second electrode hand

[26] = first electrode replacing device

[27] = second electrode replacing device

[35] = NC device.

Figure 1

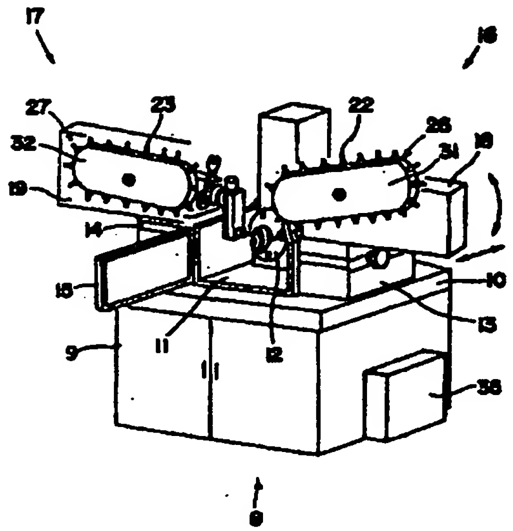

Figure 2

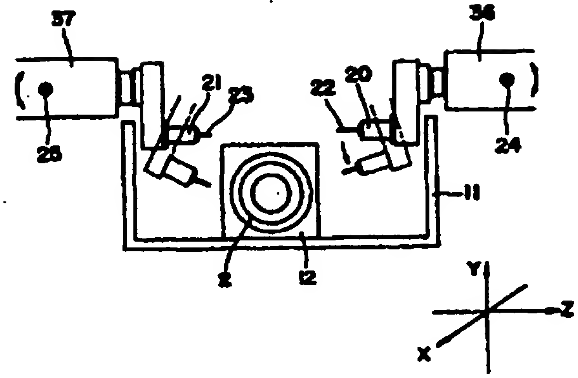

Figure 3

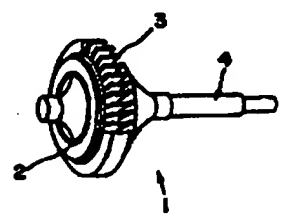

Figure 4

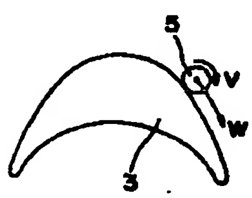

Figure 5

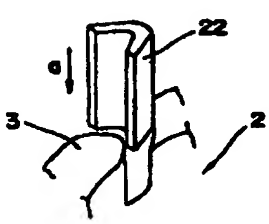

Figure 6